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INVENTOR: DOUG SMITH
DAVID VOISARD

TITLE: METHOD AND APPARATUS FOR INJECTION MOLDING

ATTORNEYS: Robert S. Mallin, Reg. No. 35,596
Sailesh K. Patel, Reg. No. 46,982
BRINKS HOFER GILSON & LIONE
POST OFFICE BOX 10395
CHICAGO, ILLINOIS 60610
(312) 321-4200

METHOD AND APPARATUS FOR INJECTION MOLDING

BACKGROUND

The present invention relates to a method and apparatus for injection molding, and in particular, to a method and apparatus for molding injection molded parts.

Conventionally, a variety of methods have been utilized for injection molding in various fields. Of these methods, a molding metal mold of a runnerless (hot runner) system has been widely used.

There are a variety of molds in such a hot runner system. Smaller molds generally only require one inlet for injecting molten material. For larger molds, several inlets are used to inject molten material at different points within the mold cavity. These larger molds are sometimes referred to as multi-gate mold cavities. In multi-gate mold cavities, the pressure of molten material differs at various points inside the cavity. The pressure typically becomes constant throughout the cavity once the cavity is completely filled with molten material.

A conventional molding process can be done using power from hydraulic means or electrical means. The molding process uses two platens, a movable platen and a stationary platen. In a process using hydraulic means, a hydraulic cylinder applies a certain force to push a movable platen against a stationary platen. Molding members within or attached to the platens form a molding cavity. The force is maintained on the stationary platen or die plate while a molten material is injected into the molding cavity. The molten material is injected into the cavity with a resin feeding screw until the pressure inside the cavity reaches a predetermined molding pressure or until the screw has moved a predetermined distance and for a set period of time, thereby ensuring that the cavity is filled. After injecting the molten material, the molten material is allowed to cool and solidify, the force is then released, and the plates are separated and the process begins anew.

Some injection molding machines use a mold with only one cavity, thereby allowing for the production of one molded object per cycle. Total cycle time is the sum of the fill time and the cool down time. The cool down time is generally substantially longer than the fill time. For example, a typical fill time is about 5 seconds, whereas a typical cooling time is about 30 seconds, for a total of about 35 seconds for the production of one molded article.

To reduce process time per molded article, some injection molding machines utilize molds with a plurality of cavities for forming a plurality of molded articles. The molten material fills into each of the cavities simultaneously. While this may extend the fill time a few seconds, for example for mold cavities for car doors, to about 8 seconds, the cooling time remains fixed at about 40 seconds. The total time of this process is about 48 seconds for the production of two molded articles. Thus, using multiple cavities increases the efficiency almost two-fold.

A problem with the multiple cavity method, however, is that the mold clamping force must also be doubled since the article molding area is doubled. As a result, a larger injection molding machine must be used to apply the extra force needed to hold the molding platens together. A larger injection molding machine costs more, takes up more floor space, and requires more power. Therefore, using multiple cavity molds with the conventional method can sacrifice cost for greater time efficiency.

Furthermore, for molding larger articles, the molten material is injected at several different points in the mold cavity. This is due to the limits on the flow of molten plastic. These larger mold cavities are commonly known as multi-gate mold cavities. An example of an article that would require a multi-gate mold cavity is an interior car door panel, which typically requires four or five gates per single cavity mold. In the manufacture of such parts, it is desirable to maintain the injected pressure of the molten material constant so that the part is formed accurately. Without maintaining the pressure constant, the structural accuracy of the formed part may suffer. For example, the resulting part may include short

shots, ripples, or other dimensional inaccuracies. As such, there is a need to be able to accurately measure the pressure of molten plastic inside of the mold cavity.

Accordingly, a general object of the present invention is to provide an injection molding machine and a method for injection molding either large or small articles where there is process control for each cavity..

A further object of the present invention is to provide an injection molding machine and a method for injection molding large articles with greater efficiency and reduced costs.

BRIEF SUMMARY

In one aspect, the invention is a method for sequentially injecting a molten material comprising clamping a stationary platen and a movable platen at a clamping force to define at least two cavities, opening a first valve gate to inject a molten material into a first cavity, closing the first valve gate either by position, time or pressure switch, opening a second valve gate to inject the molten material into a second cavity, and closing the second valve gate when the desired position, time or pressure switch value has been met.

In a second aspect, the invention is an injection molding apparatus comprising a mold having at least two mold cavities, a molten material inlet system in communication with said at least two mold cavities, at least two valve gates in said molten material inlet, wherein each of said at least two valve gates are associated with one of said mold cavities; and a controller adapted to sequentially open and close said valve gates.

In a third aspect, the invention is a controller for use with a injection molding device having a mold with at least two cavities, the controller comprises means for opening a first valve gate associated with a first mold cavity to initiate a flow of molten material into the first mold cavity, means for closing the first valve gate by either position, time or pressure switch, means for opening a second valve gate associated with a second cavity to initiate a flow of molten material into a second mold cavity, and means for closing the second valve gate by either position, time or pressure switch.

Other objects, features and advantages of the present invention will become apparent from the following detailed description. It should be understood, however, that the detailed description and the specific examples, while indicating embodiments of the invention, are given by way of illustration only, the invention being defined only by the claims following this detailed description.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

The following drawings form part of the present specification and are included to further demonstrate certain aspects of the present invention. The invention may be better understood by reference to one or more of these drawings in combination with the detailed description of specific embodiments presented herein:

FIG. 1 is a schematic view of an injection molding apparatus suitable for the method of injection molding a molten material, provided by the present invention.

FIG. 2 is a schematic view of a part of the injection molding apparatus showing a state immediately after clamping the mold, and a state in which the introduction of the molten material is initiated, in the method of injection molding, provided by the present invention.

FIG. 3 is a perspective view of a part of the injection molding apparatus showing a multi-gate injection molding system with multiple multi-gate molds, in the method of injection molding, provided by the present invention.

FIG. 4 is a flowchart illustration of the sequential injection molding process of the present invention.

FIG. 5 schematically shows a change in injection velocity with time for a conventional injection molding method and a sequential injection molding method.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First, the injection molding apparatus suitable for use in the method of injection-molding a thermoplastic or thermoset resin, provided by the present

invention, will be outlined below with reference to FIG. 1. Although the injection molding apparatus described and shown in FIG. 1 uses hydraulic power, one of ordinary skill in the art would recognize that an electrically powered molding apparatus can also be used for the present invention. The injection molding apparatus includes an injection cylinder **12** having a resin-feeding screw or extrusion screw **10** inside, a stationary platen **40**, a movable platen **44**, an inlet **26**, tie bars **34**, a clamping hydraulic cylinder **30** and a hydraulic piston **32**. The movable platen **44** is actuated with the hydraulic piston **32** in the hydraulic cylinder **30** to move in parallel on the tie bars **34**.

A mold is formed by a stationary mold member **36** and a movable mold member **46**. The stationary mold member **36** is attached to the stationary platen **40**, and the movable mold member **46** is attached to the movable platen **44**. The platens **40**, **44**, the tie bars **34**, and the cylinder **30** and piston **32** define a clamping system for applying a clamping pressure to the mold members **36**, **46**. The movable platen **44** is moved towards the stationary platen **40** until the movable mold member **46** is engaged with the stationary mold member **36**, and the mold is clamped to form multi-gate cavities **22**, **24**. This clamped position is illustrated in FIG. 2.

After the mold has been clamped, the clamping force is controlled with the clamping hydraulic cylinder **30**. The clamping force may also be controlled by toggle or an electric machine. The molten material flows into the cavities **22**, **24** via inlets **26**. Valve gates **50**, **52** may be used, but are not necessary, to open and close inlets **26**. If used, valve gates **50**, **52** would face cavities **22**, **24** and at least one valve gate is associated with each cavity **22**, **24** respectively. After the molten material cools and hardens, the clamping force is released and the movable platen **44** is moved away from the stationary platen **40**, in order to release the molded product.

For the exemplary two-cavity multi-gate mold shown in FIG. 2, the sequential injection molding method begins with clamping the mold with at a mold clamping force. The controller **60** then closes valve gate **52** and opens valve gate **50**. Molten material fills cavity **22**. The amount of material that enters the

cavity may be controlled by the use of pressure transducers **P1**, **P2** or preferably can be controlled by predetermining the distance or time the resin feeding screw **10** must travel to fill cavity **22**. Conventional molding processes use the position of the resin feeding screw **10** to control the amount of material being injected into the mold cavity and to ensure that the cavity is full and packed. Sometimes, the time the screw travels is the controlling variable in filling the cavity.

As molten material enters through the inlet, it gradually fills the entire cavity. A stroke sensor or potentiometer **65** measures the distance resin feeding screw **10** has moved and transmits this reading to the controller **60**. The controller **60** uses the data from the stroke sensor and/or a timer to determine when to close valve gate **50** to stop the flow of molten material into cavity **22** and open valve gate **52** to start the flow of molten material into cavity 24. The controller closes valve gate **50** when the resin feeding screw has traveled a pre-determined distance or for a predetermined period of time. If no hold pressure is used in molding the article, the valve gate **50** is closed at the switchover point which is the point when the entire cavity gets filled with molten material and begins to exert a pressure on the cavity. If a hold pressure is used, the valve gate is kept open for a fixed period of time after the molten material has filled the entire cavity and the resin feeding screw exerts a holding pressure. After the fixed period of time the valve gate **50** is closed. If pressure transducers are used, the controller closes valve gate **50** and opens valve gate **52** when the pressure inside the cavity reaches a set point pressure. The controller opens valve gate **52** and the resin feeding screw may then retreat back or may continue from its end position depending on whether or not there is enough material in the injection chamber to fill the second cavity **24**. In a preferred embodiment, the pressure exerted by the resin feeding screw is decreased between the closing of valve gate **50** and the opening of valve gate **52**. In the alternative, the screw is activated after delay time of about 0.5 seconds after opening valve gate **52**. This prevents a sudden high pressure shot upon the opening of valve gate **52** and provides greater control of the process. Molten material then fills into cavity **24**. When the resin feeding screw **10** has moved the predetermined distance or time to fill and pack cavity **24**, the molten material is

held inside cavities **22**, **24** and is allowed to cool and solidify. At this point, valve gate **52** may be left open if there are no additional mold cavities to be utilized, otherwise the controller closes valve gate **52** and the process repeats.

FIG. 3 shows a perspective view an embodiment of the multiple multi-gate mold injection system of the present invention. In particular, there are two multi-gate mold cavities for interior car door panels **71**. Molten material enters into the main inlet **75** and then flows into the multi-drop hot manifold **76** that has inlets at various points in the mold cavity. Pressure transducers **73**may be placed inside the cavity, preferably at the end of fill point **72,** to measure the pressure inside the cavity. Ejector pins **74** release the molded article once the molten material cools and solidifies.

FIG. 4 is a flowchart illustration of the sequential injection molding process of the present invention. It will be understood that each step of the flowchart illustration can be implemented by computer program instructions or can be done manually. These computer program instructions may be loaded onto a computer or other programmable data processing apparatus to produce a machine, such that the instructions which execute on the computer or other programmable data processing apparatus create means for implementing the functions specified in the flowchart step. These computer program instructions may also be stored in a computer-readable memory that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable memory produce an article of manufacture including instruction means which implement the function specified in the flowchart step. The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide steps for implementing the functions specified in the flowchart step.

It will be understood that each step of the flowchart illustration can be implemented by special purpose hardware-based computer systems which perform the specified functions or steps, or combinations of special purpose hardware and computer instructions, or can be done manually.

An injection molding machine utilizing a sequential injection molding process has a plurality of multi-gate mold cavities formed by the movable mold member **46** and the stationary mold member **36**. For an injection molding machine with *m* cavities, where *n* equals 1 to *m*, the process begins with step **100** by closing the clamp with a mold clamping force calculated by the equation:

mold clamping force required = (clamp tonnage required per square inch) x (surface area of cavity *n*)

The clamp tonnage is predetermined and is calculated based upon the type of molding material and the desired characteristics of the molded article. For example, an ABS material may require two to three tons of pressure per square inch of area. Other materials require different amounts of pressure. In step **110**, a first valve gate is opened which faces a first cavity. The first cavity is then injected with molten material using a resin-feeding screw at a predetermined injection velocity in step **120**. The injection velocity may be changed or may be kept constant as the cavity becomes filled with molten material. The time it takes to fill the cavity to the V/P change over position or the set-point pressure depends on the size of the cavity and the injection velocity. In a preferred embodiment, the injection velocity is varied and it takes about one second to about ten seconds to fill the cavity to the set-point pressure or V/P change over position. In step **130**, the controller monitors the distance, time and/or velocity at which the resin screw has moved and compares it to the set-point values said screw must move in order for molten material to fill the cavity or reach the velocity to pressure (V/P) switch point. The V/P switch point occurs when the molten material has fully filled the cavity and begins to exert a pressure inside the cavity. In one embodiment, if a predetermined holding pressure at which the material must be held is used, resin feeding screw exerts a holding pressure for a predetermined time before the controller closes the valve gate to the cavity.. The process goes back to step **120** if

the cavity is not full or has not reached the V/P switch point if there is no holding pressure, or has not reached a predetermined holding pressure if using holding pressure or has not reached the pressure switch set value. The first valve gate is closed once the cavity is full if not using holding pressure or once it is full and has been held for a predetermined period of time at a holding pressure or has reached the pressure switch set value in step **140**. The process goes back to step **110** and repeats for *n* cavities. After all of the cavities are full, the machine recovers for the next shot in step **150** the molten material inside the cavities is allowed to cool and solidify in step **160**. The cooling process takes about 20 seconds to about 40 seconds, depending upon the size of the molded article and the type and temperature of the molded material. After cooling, the mold clamping force is released and the clamp is opened in step **170**. The sequential injection molding process ends with step **180**, when the molded articles are ejected from the molding cavities.

The mold clamping force required is reduced significantly in a sequential injection molding process for a multiple cavity mold. This is because the area to be pressurized does not increase when there are multiple cavities. For a mold with multiple cavities, the area to be pressurized remains constant and equals the area of one cavity since each cavity in the mold is pressurized and closed sequentially. Therefore, the mold clamping force required in a two-cavity mold is reduced to almost half by using the sequential injection molding method compared to a conventional method. The mold clamping force required in a three-cavity mold the force required is reduced by over fifty percent compared to the force required in the conventional method. This significant reduction in mold clamping force allows for a reduction in the press size, which in turn allows for dramatic cost savings in terms of production cost per molded article.

FIG. 5 shows how the injection velocity varies during the step of filling a cavity for a standard injection molding process compared to a sequential injection molding process in a two-cavity mold. The injection velocity is controlled by the machine set-point of the resin-feeding screw **10**. In a standard injection molding process the cavities are filled with molten material simultaneously and in the

sequential method the cavities are filled sequentially. Both processes may be carried out with more than two cavities. The sequential molding process, however, has at least two cavities.

In a standard injection molding process, the injection pressure is set above the necessary pressure requirement to fill the mold cavity. The injection velocity of the molten material is set at a filling flow rate prior to the valve gate being opened. As illustrated in FIG. 5, the injection velocity is kept at filling flow rate until the cavities are almost full. The injection velocity is then gradually tapered down from the filling flow rate so that the injection velocity of the molten material can be controlled to allow proper fill of the entire cavity. Once the pressure inside the cavity reaches the set-point molding pressure, the injection velocity is brought down to zero or if molding by position when the cavity reaches the desired fill level. Decreasing the injection velocity ensures that the molten material is uniform inside the cavities, thereby yielding a higher quality molded article.

In the sequential injection molding process, the injection pressure is set above the necessary pressure requirement to fill the mold cavity. This pressure requirement is dependent on the physical properties of the molten material such as its viscosity. The injection velocity of the molten material is set at a filling flow rate when a valve gate is opened. The injection velocity is kept at the filling flow rate until a cavity is almost full and then gradually tapered down until the cavity is full at the switchover point or if holding pressure is utilized until the hold timer times out. The difference in the sequential method compared to the standard method, is that the injection velocity is increased again to the filling flow rate when the second valve gate is opened. This adds approximately 0.5 seconds to about 4 seconds to the total fill-time for the process. In a preferred embodiment, the ramp up of the injection velocity to the filling flow rate is rapid so that the total process time does not increase significantly.

It is contemplated that numerous modifications may be made to the injection molding method and apparatus of the present invention without departing from the spirit and scope of the invention as defined in the claims. For example, while the exemplary embodiment shown in the drawings has two multi-gate mold

cavities, those skilled in the art will appreciate that the same sequential steps can be used to control the flow of molten material into molds having more than two cavities. In addition, for molds having more than two cavities, there may be a valve gate associated with each cavity, with each valve gate opened and closed sequentially. Alternately, for molds having more than two cavities, there may be fewer valve gates than cavities, as long as there are at least two cavities. In this embodiment, at least one of the valve gates would control the inlet to at least two cavities. Accordingly, while the present invention has been described herein in relation to several embodiments, the foregoing disclosure is not intended or to be construed to limit the present invention or otherwise to exclude any such other embodiments, arrangements, variations, or modifications and equivalent arrangements. Rather, the present invention is limited only by the claims appended hereto and the equivalents thereof.